[Document Name] Specification

[Title of the Invention]

BUMP FORMATION METHOD AND BUMP FORMING APPARATUS

[What is claimed is]

[Claim 1] A bump formation method for forming bumps onto electrodes of a circuit formed to a semiconductor wafer, the method characterized by comprising:

after bonding the bumps on the semiconductor wafer by practical heating for bump formation and before storing the semiconductor wafer in a storage container, carrying out a post-heating operation in which a temperature drop of the semiconductor wafer is controlled, to the semiconductor wafer.

[Claim 2] The bump formation method according to claim 1, wherein the post-heating operation is effectuated after the completion of the bump bonding by arranging the semiconductor wafer in a non-contact state to the bonding stage above the bonding stage which heats the semiconductor wafer to a temperature for bump bonding in the practical heating necessary to form bumps on electrodes formed to the circuit on the semiconductor wafer.

[Claim 3] The bump formation method according to claim 1, wherein the post-heating operation is effectuated after the completion of the bump bonding by arranging the semiconductor wafer to a cooling position displaced from above the bonding stage.

[Claim 4] The bump formation method according to any

one of claims 1-3, wherein the post-heating operation is executed in accordance with a preliminarily set program for post-heating.

[Claim 5] The bump formation method according to any one of claims 1-3, wherein the post-heating operation is executed while a temperature of the semiconductor wafer is actually measured.

[Claim 6] The bump formation method according to any one of claims 2, 4 and 5, wherein the temperature drop in the post-heating operation is controlled by changing at least one of a size of a gap between the bonding stage and the semiconductor wafer, and an arrangement time while the semiconductor wafer is placed in the non-contact state to the bonding stage above the bonding stage.

[Claim 7] The bump formation method according to claim 6, wherein the temperature drop in the post-heating operation is effectuated by controlling to change at least one of the gap size and the arrangement time by a plurality of the number of times.

[Claim 8] The bump formation method according to any one of claims 1-7, wherein the post-heating operation is controlled on a basis of at least one of a material and a thickness of the semiconductor wafer.

[Claim 9] The bump formation method according to any one of claims 1-8, wherein a preheating operation to the semiconductor wafer is preliminarily carried out before the execution of the practical heating.

[Claim 10] The bump formation method according to claim 9, wherein the preheating operation is achieved by arranging the semiconductor wafer in a non-contact state to the bonding stage above the bonding stage when the practical heating is carried out with the semiconductor wafer being placed on the bonding stage which heats the semiconductor wafer to the temperature for bump bonding.

[Claim 11] The bump formation method according to claim 9 or 10, wherein the preheating operation is executed in accordance with a preliminarily set program for preheating.

[Claim 12] The bump formation method according to claim 9 or 10, wherein the preheating operation is executed while a temperature of the semiconductor wafer is actually measured.

[Claim 13] The bump formation method according to any one of claims 10-12, wherein a temperature rise in the preheating operation is controlled by changing at least one of a size of a gap between the bonding stage and the semiconductor wafer, and the arrangement time while the semiconductor wafer is placed above the bonding stage.

[Claim 14] The bump formation method according to claim 13, wherein the temperature rise in the preheating operation is effectuated by controlling to change at least one of the gap size and the arrangement time by a plurality of the number of times.

[Claim 15] The bump formation method according to any one of claims 9-14, wherein the preheating operation is

controlled on the basis of at least one of the material and the thickness of the semiconductor wafer.

[Claim 16] The bump formation method according to any one of claims 9-15, wherein in a case of executing both the preheating operation and the post-heating operation, a temperature change ratio per unit time is more minutely set for the temperature drop control in the post-heating operation than the temperature rise control in the preheating operation.

[Claim 17] The bump formation method according to any one of claims 1-16, wherein the semiconductor wafer is a compound semiconductor wafer.

[Claim 18] The bump formation method according to any one of claims 1-17, wherein before the bump bonding is carried out after the semiconductor wafer is placed on the bonding stage which heats the semiconductor wafer to the temperature for bump bonding in the practical heating, a temperature difference between a temperature at a side of a stage contact face (211b) of the semiconductor wafer in contact with the bonding stage and a temperature at a side of a circuit formation face (211a) of the semiconductor wafer opposite to the stage contact face is controlled for the semiconductor wafer placed on the bonding stage to be within a warpage non-generation temperature range whereby a warpage of the semiconductor wafer is restricted to a level not obstructing the bump formation.

[Claim 19] The bump formation method according to claim

18, wherein the control to within the warpage non-generation temperature range is achieved by heating the circuit formation face side of the semiconductor wafer placed on the bonding stage.

[Claim 20] The bump formation method according to claim 19, wherein the heating to the circuit formation face side is carried out by blowing to the circuit formation face a heating air of a temperature which keeps the temperature difference within the warpage non-generation temperature range.

[Claim 21] The bump formation method according to claim 18, wherein the control to within the warpage non-generation temperature range is achieved by cooling the stage contact face side of the semiconductor wafer placed on the bonding stage.

[Claim 22] The bump formation method according to claim 21, wherein the cooling to the stage contact face side is carried out by blowing to the stage contact face a cooling air of a temperature which keeps the temperature difference within the warpage non-generation temperature range.

[Claim 23] The bump formation method according to any one of claims 18-22, wherein the warpage non-generation temperature range is within 20°C.

[Claim 24] The bump formation method according to any one of claims 18-23, wherein the semiconductor wafer is a quartz-based wafer.

[Claim 25] A bump forming apparatus which includes a

bonding stage (110) where a semiconductor wafer is placed and which practically heats the semiconductor wafer to a temperature for bump bonding necessary to form bumps on electrodes formed to a circuit of the semiconductor wafer, a bump forming head (120) placed on the bonding stage for forming the bumps onto the electrodes of the semiconductor wafer, and a load and transfer device (140) for putting and removing the semiconductor wafer to the bonding stage,

said bump forming apparatus further comprising a post-heating device (110, 140, 180) for cooling the semiconductor wafer based on a temperature drop control to the semiconductor wafer after the bump bonding to the practically heated semiconductor wafer.

[Claim 26] The bump forming apparatus according to claim 25, wherein the post-heating device having the bonding stage, the load and transfer device and a first control device (180-1) carries out a post-heating operation to the semiconductor wafer with utilization of heat of the bonding stage, said first control device placing the load and transfer device holding the semiconductor wafer to a position above the bonding stage heated to the temperature for bump bonding where the semiconductor wafer is in non-contact to the bonding stage.

[Claim 27] The bump forming apparatus according to claim 26, wherein the first control device controls a temperature drop at the semiconductor wafer in the post-heating operation by changing at least one of a size of a

gap between the bonding stage and the semiconductor wafer, and an arrangement time while the semiconductor wafer is placed above the bonding stage.

[Claim 28] The bump forming apparatus according to claim 27, wherein the temperature drop control in the post-heating operation by the first control device is effectuated by controlling to change at least one of the gap size and the arrangement time by a plurality of the number of times.

[Claim 29] The bump forming apparatus according to any one of claims 26-28, wherein the first control device executes the post-heating operation in accordance with a preliminarily set program for post-heating.

[Claim 30] The bump forming apparatus according to any one of claims 26-28, which has a first temperature measuring device (1419) for measuring a temperature of the semiconductor wafer subjected to the post-heating operation, so that the first control device controls the post-heating operation on a basis of the temperature of the semiconductor wafer actually measured by the first temperature measuring device.

[Claim 31] The bump forming apparatus according to any one of claims 26-30, wherein the first control device controls the post-heating operation on a basis of at least one of a material and a thickness of the semiconductor wafer.

[Claim 32] The bump forming apparatus according to any one of claims 25-31, which further includes a preheating device (110, 140, 180) for carrying out a preheating

operation to the semiconductor wafer before the semiconductor wafer placed on the bonding stage is heated to the temperature for bump bonding.

[Claim 33] The bump forming apparatus according to claim 32, wherein the preheating device having the bonding stage, the load and transfer device and a second control device (180-2) carries out a preheating operation to the semiconductor wafer with utilization of heat of the bonding stage, said second control device placing the load and transfer device holding the semiconductor wafer to a position above the bonding stage heated to the temperature for bump bonding where the semiconductor wafer is in non-contact to the bonding stage.

[Claim 34] The bump forming apparatus according to claim 33, wherein the second control device controls a temperature rise at the semiconductor wafer in the preheating operation by changing at least one of a size of a gap between the bonding stage and the semiconductor wafer, and an arrangement time while the semiconductor wafer is placed above the bonding stage.

[Claim 35] The bump forming apparatus according to claim 34, wherein the temperature rise control in the preheating operation by the second control device is effectuated by controlling to change at least one of the gap size and the arrangement time by a plurality of the number of times.

[Claim 36] The bump forming apparatus according to any

one of claims 33-35, wherein the second control device executes the preheating operation in accordance with a preliminarily set program for preheating.

[Claim 37] The bump forming apparatus according to any one of claims 33-35, which has a second temperature measuring device (1419) for measuring a temperature of the semiconductor wafer subjected to the preheating operation, so that the second control device controls the preheating operation on a basis of the temperature of the semiconductor wafer actually measured by the second temperature measuring device.

[Claim 38] The bump forming apparatus according to any one of claims 33-37, wherein the second control device controls the preheating operation on a basis of at least one of the material and the thickness of the semiconductor wafer.

[Claim 39] The bump forming apparatus according to any one of claims 25-38, which further has a storage container (205, 206) for storing the semiconductor wafers, and a transfer device (130) for transferring the semiconductor wafer to the storage container and, sending and receiving the semiconductor wafers to the load and transfer device.

[Claim 40] The bump forming apparatus according to claim 39, which further includes at least one of a first temporary holding member (271-1) for holding the semiconductor wafer (201) without bumps formed yet which is taken out from the storage container by the transfer device and, sending and receiving the semiconductor wafer to the

load and transfer device, and a second temporary holding member (271-2) for holding the semiconductor wafer (202) with bumps formed which is held by the load and transfer device from the bonding stage, and sending and receiving the semiconductor wafer to the transfer device.

[Claim 41] The bump forming apparatus according to any one of claims 26-31, and 33-40, wherein the load and transfer device has clamp mechanisms (1414) arranged via an almost equal distance in a periphery of the semiconductor wafer to prevent a dynamic stress and a thermal temperature gradient to the semiconductor wafer.

[Claim 42] The bump forming apparatus according to any one of claims 39-41, wherein the storage container includes a first storage container (205) for storing semiconductor wafers (201) without bumps formed yet and a second storage container (206) for storing semiconductor wafers (202) with bumps formed thereto.

[Claim 43] The bump forming apparatus according to any one of claims 39-42, wherein the transfer device has a loading member (2511, 2521) for loading the semiconductor wafer, having at least a contact part of the loading member to the semiconductor wafer being equipped with a thermal insulating material (2512, 2522) for delaying the temperature drop of the semiconductor wafer.

[Claim 44] The bump forming apparatus according to claim 42 or 43, wherein the transfer device has a carry-in device (131) for taking out the semiconductor wafer without

bumps from the first storage container and, a carry-out device (132) for sending out the semiconductor wafer with bumps to the second storage container.

[Claim 45] The bump forming apparatus according to claim 44, wherein the carry-out device is included in the post-heating device, with a blower (1325) for sending a gas which is controlled in temperature by the first control device to the loaded semiconductor wafer with bumps.

[Claim 46] The bump forming apparatus according to claim 45, wherein the gas is an inert gas.

[Claim 47] The bump forming apparatus according to claim 45, wherein the gas is nitrogen gas.

[Claim 48] The bump forming apparatus according to any one of claims 33-47, wherein the load and transfer device has an openable member (2621) for covering the held semiconductor wafer when at least one of the preheating operation and the post-heating operation is executed to the semiconductor wafer, thereby thermally insulating the semiconductor wafer, said member for covering being provided with an opening (2625) to let the heat enter from the bonding stage.

[Claim 49] The bump forming apparatus according to claim 48, wherein the load and transfer device further has a heat insulation assisting device (263) for blowing a temperature-controlled gas for assisting heat insulation of the semiconductor wafer to the semiconductor wafer covered with the member for covering.

[Claim 50] The bump forming apparatus according to any one of claims 40-49, wherein the load and transfer device has a first transfer device (144-1) for transferring the semiconductor wafer held by the carry-in device or the first temporary holding member to the bonding stage, and a second transfer device (144-2) for transferring the semiconductor wafer from the bonding stage to the second temporary holding member.

[Claim 51] The bump forming apparatus according to any one of claims 25-50, which further includes a wafer temperature control device (160) which controls for the semiconductor wafer placed on the bonding stage, before the bump bonding is carried out after the semiconductor wafer is placed on the bonding stage, a temperature difference between a temperature at a side of a stage contact face (211b) of the semiconductor wafer in contact with the bonding stage and a temperature at a side of a circuit formation face (211a) of the semiconductor wafer opposite to the stage contact face to be within a warpage non-generation temperature range where a warpage of the semiconductor wafer is restricted to a level not obstructing the bump formation.

[Claim 52] The bump forming apparatus according to claim 51, wherein the wafer temperature control device achieves the control to within the warpage non-generation temperature range by heating the circuit formation face side of the semiconductor wafer placed on the bonding stage.

[Claim 53] The bump forming apparatus according to

claim 52, wherein the wafer temperature control device heats the circuit formation face side by blowing to the circuit formation face a heating air of a temperature which keeps the temperature difference within the warpage non-generation temperature range.

[Claim 54] The bump forming apparatus according to claim 51, wherein the wafer temperature control device achieves the control to within the warpage non-generation temperature range by cooling the stage contact face side of the semiconductor wafer placed on the bonding stage.

[Claim 55] The bump forming apparatus according to claim 54, wherein the wafer temperature control device cools the stage contact face side by blowing to the stage contact face a cooling air of a temperature which keeps the temperature difference within the warpage non-generation temperature range.

[Claim 56] The bump forming apparatus according to any one of claims 51-55, wherein the warpage non-generation temperature range is within 20°C.

[Claim 57] The bump forming apparatus according to any one of claims 51-56, wherein the semiconductor wafer is a quartz-based wafer.

[Detailed Explanation of the Invention]

[0001]

[Technical Field to which the Invention pertains]

The present invention relates to a bump forming

apparatus for forming bumps on semiconductor wafers, and a bump formation method carried out by the bump forming apparatus.

[0002]

[Conventional Art and Subject to be solved by the Invention]

In recent years, electronic components have been made more and more compact in accordance with miniaturization of devices, e.g., portable phones and the like mounting the electronic components. Thus, there is a bump forming apparatus for this purpose which forms bumps to electrode portions at each circuit formation part on a semiconductor wafer without separating the circuit formation part from the semiconductor wafer. The bump forming apparatus of the kind includes a carry-in device for taking out a semiconductor wafer before bumps are formed thereto from a first storage container where the semiconductor wafers without bumps are stored, a second storage container for storing wafers with the bumps formed, a bonding stage where wafers without bumps are placed and heated generally to about 250-270°C so as to join the electrode portions and bumps, a carry-out device for storing the wafers after the bumps are formed thereon into the second storage container, and a transfer device for transferring the wafers from the carry-in device to the bonding stage and from the bonding stage to the carry-out device.

Meanwhile, as a SAW (Surface Acoustic Wave) filter used in the aforementioned portable phones and the like,

there are some semiconductor wafers having a substrate of the wafer not formed of silicon as in the prior art but formed of quartz, or a compound semiconductor wafer such as lithium tantalum, lithium niobium, gallium arsenide or the like. Although the compound semiconductor wafer of this type is heated as well to approximately 150°C at maximum in forming the bumps, it is necessary for the compound semiconductor wafer to be lowered in speed of heating and cooling in comparison with the conventional silicon wafer. Unless the cooling is carried out slowly, the compound semiconductor wafer is accompanied with a pyroelectric effect thereby breaking circuits or the wafer is thermally deformed to crack in some cases.

As such, a bump forming apparatus for forming bumps to the compound semiconductor wafers needs a different way of temperature control from the control in the conventional bump forming apparatus which forms bumps to silicon wafers.

The present invention has for its object to provide a bump forming apparatus which executes temperature control different from the prior art before and after forming bumps to semiconductor wafers, and a bump formation method carried out by the bump forming apparatus.

[0003]

[Means for solving the Subject]

A bump formation method is provided according to a

first aspect of the present invention for forming bumps onto electrodes of a circuit formed to a semiconductor wafer. The bump formation method is characterized by after bonding the bumps on the semiconductor wafer by practical heating for bump formation and before storing the semiconductor wafer in a storage container, carrying out a post-heating operation in which a temperature drop of the semiconductor wafer is controlled, to the semiconductor wafer.

[0004]

In a second aspect of the present invention, a preheating operation to the semiconductor wafer before the semiconductor wafer is practically heated can be added to the bump formation method of the first aspect.

[0005]

In a bump formation method according to a fifth aspect of the present invention, before the bump bonding is carried out after the semiconductor wafer is placed on a bonding stage which heats the semiconductor wafer to a temperature for bump bonding in the practical heating, a temperature difference between a temperature at a side of a stage contact face of the semiconductor wafer in contact with the bonding stage and a temperature at a side of a circuit formation face of the semiconductor wafer opposite to the stage contact face may be controlled in addition to the bump formation method of the first aspect for the semiconductor wafer placed on the bonding stage to be within a warpage non-generation temperature range whereby a warpage

of the semiconductor wafer is restricted to a level not obstructing the bump formation.

[0006]

A bump forming apparatus provided according to a third aspect of the present invention has a bonding stage where a semiconductor wafer is placed and which practically heats the semiconductor wafer to a temperature for bump bonding necessary to form bumps on electrodes formed to a circuit of the semiconductor wafer, a bump forming head placed above the bonding stage for forming the bumps onto the electrodes of the semiconductor wafer and, a load and transfer device for putting and removing the semiconductor wafer to the bonding stage,

which is characterized by further including a post-heating device for cooling the semiconductor wafer based on a temperature drop control to the semiconductor wafer after bumps are bonded on the practically heated semiconductor wafer.

[0007]

In a bump forming apparatus according to a fourth aspect of the present invention, a preheating device can be set additionally to the bump forming apparatus of the third aspect for carrying out a preheating operation to the semiconductor wafer before the semiconductor wafer placed on the bonding stage is heated to the temperature for bump bonding.

[0008]

A bump forming apparatus according to a sixth aspect of the present invention may have a wafer temperature control device added to the bump forming apparatus of the third aspect, which controls, before the bump bonding is carried out after the semiconductor wafer is placed on the bonding stage, a temperature difference between a temperature at a side of a stage contact face of the semiconductor wafer placed on the bonding stage in contact with the bonding stage and, a temperature at a side of a circuit formation face of the semiconductor wafer opposite to the stage contact face to be within a warpage non-generation temperature range where a warpage of the semiconductor wafer is restricted to a level not obstructing the bump formation.

[0009]

[Embodiments of the Invention]

First Embodiment;

A bump forming apparatus according to an embodiment of the present invention and a bump formation method carried out by the bump forming apparatus will be described with reference to the drawings. A bump forming apparatus 101 according to this embodiment shown in Fig. 1 is appropriate to process the earlier mentioned compound semiconductor wafers and will be discussed in the following description in relation to forming bumps to the compound semiconductor wafers. However, an object to be processed by

the apparatus is not limited to the compound semiconductors, and needless to say, the apparatus can process conventional silicon wafers. In such case, wafers when bumps are formed thereto are heated up to approximately 250-270°C as described before. The bump forming apparatus 101 has a first storage container 205 for storing compound semiconductor wafers 201 in layers before bumps are formed thereto and a second storage container 206 for storing compound semiconductor wafers 202 in layers after bumps are formed thereto, that is, the apparatus is a double magazine type. However, the apparatus is not restricted to the type and can be formed in the so-called single magazine type with one storage container for storing both the compound semiconductor wafers 201 without bumps and the compound semiconductor wafers 202 with bumps.

[0010]

The bump forming apparatus 101 is fundamentally not different from the bump forming apparatus of the prior art. That is, the bump forming apparatus 101 roughly consists of one bonding stage 110, one bump forming head 120, transfer devices 130, one load and transfer device 140, lifting devices 150 set to the above storage containers 205, 206 for moving up and down the storage containers 205, 206 respectively, and a control device 180. As will be described later in relation to operation of the bump forming apparatus 101, the apparatus is greatly different from the conventional apparatus in a point of executing its operation

under the control by the above control device 180 so as to effectuate temperature control to prevent particularly compound semiconductor wafers from cracking or the like. Each of the above parts constituting the apparatus will be described below.

[0011]

The bonding stage 110 has thereon the compound semiconductor wafer before bumps are formed (referred to simply as "pre-wafer" hereinbelow) 201, and moreover heats the pre-wafer 201 to a temperature for bump bonding which is necessary for forming bumps onto electrodes of circuits formed on the pre-wafer 201.

The bump forming head 120 is a known device for forming bumps to the electrodes of the pre-wafer 201 loaded on the bonding stage 110 and heated to the temperature for bump bonding, which has not only a wire supply part 121 for supplying a gold wire as a material for the bumps, but a bump formation part for melting the gold wire thereby forming a ball and pressing the molten ball to the electrode, an ultrasonic wave generation part for acting ultrasonic waves to the bump at the time of the above pressing, etc. The thus constituted bump forming head 120 is set on an X, Y-table 122 having, for example, ball screw structures movable in X, Y-directions orthogonal to each other on a plane, and moved in the X, Y-directions by the X, Y-table 122 so that the bump can be formed to each of the electrodes

of the fixed pre-wafer 201.

[0012]

The bump forming apparatus 101 has the transfer devices 130 of two kinds. A carry-in device 131 of one of the transfer devices is a device for taking out the pre-wafer 201 from the first storage container 205, while a carry-out device 132 of the other of the transfer devices is a device for transferring and storing the compound semiconductor wafer after bumps are formed (referred to simply as "post-wafer" below) 202 to the second storage container 206. More specifically, as indicated in Fig. 2, the above carry-in device 131 and the above carry-out device 132 are arranged side by side in the X direction. The devices are moved independently of each other by movable parts 134a of rodless cylinders 134 fixed to a frame 133 while being guided by guide members 135 secured to the frame 133. As shown in Fig. 1, between the carry-in device 131 and carry-out device 132 is placed the bonding stage 110. Therefore the carry-in device 131 moves between the first storage container 205 and bonding stage 110, and the carry-out device 132 moves between the bonding stage 110 and second storage container 206.

[0013]

The carry-in device 131 has, as shown in Fig. 2, a move-side holding member 1311 and a fixed-side holding member 1312 which are both set to a supporting member 1314. The pre-wafer 201 can be loaded on the move-side holding

member 1311. The move-side holding member 1311 can be moved in a diametrical direction of the pre-wafer 201 by a driving part 1313 set to the supporting member 1314 and having an air cylinder. The driving part 1313 moves the move-side holding member 1311 in a direction to be away from the fixed-side holding member 1312, namely, in an open direction. On the other hand, moving the move-side holding member 1311 in a direction to approach the fixed-side holding member 1312, i.e., in a close direction is done by an urging force of an elastic member, e.g., spring or the like. The move-side holding member 1311 is moved in the open direction to move the carry-in device 131 by the movable part 134a of the rodless cylinder 134 to a position corresponding to the pre-wafer 201 in the first storage container 205, and then the holding member 1311 is moved in the close direction, whereby the pre-wafer 201 is caught by positioning rollers 1315 set to the move-side holding member 1311 and position regulation rollers 1316 set to the fixed-side holding member 1312. The first storage container 205 is set to a first lifter 151 constituting the lifting device 150. The first lifter 151 moves up and down the first storage container 205 so that the pre-wafer 201 is disposed to a position where the wafer can be taken out by the carry-in device 131. The pre-wafer 201 taken out from the first storage container 205 by the carry-in device 131 is held by the load and transfer device 140. The above-described operation of the carry-in device 131 is controlled by the control device 180.

[0014]

The carry-out device 132 has a loading member 1321 for loading thereon post-wafer 202 transferred from the load and transfer device 140. The loading member 1321 has a plurality of suction holes 1322 for sucking and holding the post-wafer 202. The holes 1322 formed in an array corresponding to nearly central parts of loaded post-wafer 202 are connected to a suction device 1323 controlled to operate by the control device 180. In one of features of the embodiment, the carry-out device 132 is provided with a plurality of air blast holes 1324 formed adjacent to the suction holes 1322 for jetting a gas for controlling to cool the post-wafer 202. These air blast holes 1324 are connected to an air blast device 1325 controlled in operation by the control device 180. Post-wafer 202 loaded on the loading member 1321 can be cooled more slowly than in the case of natural cooling by the temperature-controlled gas, that is, temperature-controlled air in the embodiment which is jetted from the air blast holes 1324 by the air blast device 1325. The air jetted out from the air blast holes 1324 are discharged outside the loading member 1321 through discharge grooves 1326 formed in the loading member 1321. The air blast holes 1324 are opened to the discharge grooves 1326, while the suction holes 1322 are opened to a surface 1321a of the loading member 1321 to which the post-wafer 202 comes in contact. Since the air jetted from the air blast holes 1324 passes the discharge grooves 1326, the

problem that the post-wafer 202 is blasted off the loading member 1321 because of the jetted air is eliminated. The number of the air blast holes 1324, discharge grooves 1326 and suction holes 1322 is not limited to as indicated in the drawing.

The above air blast holes 1324, air blast device 1325 and discharge grooves 1326 may be also arranged to a member of the carry-in device 131 where wafer 201 is loaded, i.e., to the move-side holding member 1311 in the embodiment.

[0015]

The load and transfer device 140 shifts the pre-wafer 201 from the above-described carry-in device 131 to the bonding stage 110 and shifts the post-wafer 202 from the bonding stage 110 to the carry-out device 132. As shown in Fig. 3, the load and transfer device has one holding part 141 for holding wafer 201, 202, a drive part 142 in a ball screw structure driven by a motor 1421 for moving the holding part 141 in the X-direction, and a move part 143 for moving the holding part 141 up and down in a thicknesswise direction of the held wafer 201, 202. The holding part 141 can be disposed immediately above each of the bonding stage 110, move-side holding member 1311 and fixed-side holding member 1312 of the carry-in device 131, and loading member 1321 of the carry-out device 132, thereby transferring the wafer 201, 202 among the bonding stage, carry-in device 131 and carry-out device 132 through the up, down movement by the move part 143. The load and transfer device 140

constituted as above is controlled in operation by the control device 180. As is indicated in Fig. 3, the load and transfer device 140 may be equipped with a temperature measuring device 1419 which can measure a temperature of the held wafer 201, 202 in a noncontact state and send the measured result to the control device 180.

[0016]

As shown in Figs. 3 and 5, the holding part 141 includes, according to one of the features of the embodiment, first clamp members 1411-1, 1411-2 of a pair (referred to as a "first clamp member 1411" collectively in some cases) and second clamp members 1412-1, 1412-2 of a pair (referred to as a "second clamp member 1412" collectively in some cases) for holding the wafers 201, 202 respectively from two directions orthogonal to each other on each plane of the wafers 201, 202. The holding part 141 also has a driving mechanism 1413 for bringing the first clamp members 1411-1, 1411-2 and second clamp members 1412-1, 1412-2 away from each other and close to each other. Two units of clamp mechanisms 1414 are arranged to positions opposite to each other between the first clamp member 1411-1 and first clamp member 1411-2 of the first clamp member 1411, and clamp mechanisms 1414 of one unit are set to positions opposite to each other between the second clamp member 1412-1 and second clamp member 1412-2 of the second clamp member 1412. Each of these clamp mechanisms 1414 has, as is clear in Fig. 6, a housing 1415, a pin 1416 penetrating the first clamp member

1411, second clamp member 1412 in a thicknesswise direction thereof which moves slidably in the housing 1415 along an axis direction thereof, a holding metal fitting 1417 fitted to an end part of the pin 1416 in a state to be rotatable in a direction about an axis of the pin 1416 and having a drop prevention flange 1418 for the wafer 201, 202, and a spring 1418 installed in the housing 1415 for urging the pin 1416 in the axis direction. The clamp mechanisms 1414 are set at 6 points via an almost equal distance along the periphery of the wafer 201, 202 held by the first clamp member 1411 and second clamp member 1412, and therefore the holding metal fittings 1417 hold the wafer 201, 202 at the 6 points.

[0017]

The embodiment is provided with not only the first clamp member 1411, but the second clamp member 1412, thereby holding the wafer 201, 202 at 6 points via the almost equal distance as mentioned above. Accordingly, application of a dynamically biased stress to the wafer 201, 202, and moreover, application of a thermally biased temperature distribution to the wafer are eliminated. Since the holding metal fittings 1417 hold the wafer 201, 202 while keeping contact with the periphery of the wafer 201, 202, especially in the post-wafer 202 in heated state, heat is transmitted from the post-wafer 202 to the holding metal fittings 1417. However the holding metal fittings 1417 apply no thermally biased temperature distribution to the post-wafer 202 even when holding the post-wafer 202, because the holding metal

fittings 1417 are arranged at 6 points via the almost equal distance. In the arrangement of the embodiment in which both the first clamp member 1411 and the second clamp member 1412 are provided and also the wafer 201, 202 is held at 6 points via the almost equal distance, generation of troubles such as the earlier-referred crack or the like to the compound semiconductor wafers which are sensitive to a temperature change and need to be cooled more slowly than silicon wafers particularly after bumps are formed thereon is effectively prevented.

[0018]

Furthermore, since the pins 1416 are movable in the axis direction, the holding metal fittings 1417 can move in the axis direction as well. For instance, the heated post-wafer 202 is sometimes accompanied with warpage because of the heat when held from the bonding stage 110. The post-wafer 202 returns from the above deflect state to the original flat state as being cooled when held by the holding metal fittings 1417. The holding metal fittings 1417 can move in the axis direction following the restoration of the post-wafer 202, and therefore the clamp mechanisms 1414 prevent generation of a stress to the wafer 202.

[0019]

The driving mechanism 1413 for bringing the first clamp member 1411 and second clamp member 1412 close to or away from each other respectively has a cylinder 14131 as a driving source and a second clamp member moving mechanism

14132 for moving the second clamp members 1412-1, 1412-2 synchronously with the movement of the clamp member 1411-2. The second clamp member moving mechanism 14132 is formed in a structure in which a first member 14133 coupled at one end to the first clamp member 1411-2 is coupled to a second member 14135 rotatable in a circumferencial direction of a rotational center shaft 14134 via a joint part 14136. The first member 14133 moves in accordance with the movement of the first clamp member 1411-2 in the X-direction, and consequently the second member 14135 rotates, thereby moving the second clamp member 1412 in the Y-direction.

[0020]

The driving mechanism 1413 operates in a manner as described hereinbelow. In order to separate the first clamp member 1411 and second clamp member 1412 to hold the wafer 201, 202, the cylinder 14131 operates to extend an output shaft 14137 in the X-direction until the first clamp member 1411-1 coupled to the output shaft 14137 butts with a stopper in the X-direction. The first clamp member 1411-2 moves in the X-direction as the movement of the first clamp member 1411-1 is stopped by the stopper. In accordance with this movement of the first clamp member 1411-2, the second clamp member 1412 moves in the Y-direction by the action of the second clamp member moving mechanism 14132 as described above. In the case where the first clamp member 1411 and second clamp member 1412 are to be separated from each other as above, the first clamp member 1411-1 first moves, then

the first clamp member 1411-2 and the second clamp member 1412 move simultaneously. On the other hand, in the case where the first clamp member 1411 and second clamp member 1412 are to be brought close to each other so as to hold the wafer 201, 202, the first clamp member 1411-2 and second clamp member 1412 move at the same time by the action of the cylinder 14131, and then the first clamp member 1411-1 moves.

A time difference is set as above in operation timing between the first clamp member 1411-2 and second clamp member 1412, and the first clamp member 1411-1, which prevents a force from acting at one time to the wafer 201, 202 particularly when the wafer 201, 202 is held.

[0021]

According to the embodiment, the above-described bonding stage 110, the load and transfer device 140, and the control device 180 constitute a preheating device for the pre-wafer 201 and a post-heating device. Although one control device 180 controls the operation of the preheating device and post-heating device in the present embodiment, a second control device 180-2 and a first control device 180-1 may be set corresponding to the preheating device and the post-heating device respectively for controlling the devices. In addition, the carry-out device 132 to which the temperature-controlled gas is jetted through air blast holes 3124 formed to the loading member 1321 by the air blast device 1325, or a modified example of the carry-out device with an insulating material set to the loading member which

will be described later and shown in Figs. 11-13 may be included in the post-heating device.

Alternatively, each group having the bonding stage 110, the load and transfer device 140, and the control device 180 can be constructed as the above preheating device and the post-heating device respectively. In this constitution, each of control devices for the preheating device and the post-heating device may be integrated to one. Further in the constitution, the carry-out device 132 to which the temperature-controlled gas is jetted or the carry-out device with the insulating material may be similarly included in the post-heating device.

[0022]

Operation of the bump forming apparatus 101 in the embodiment constituted as described hereinabove will be depicted below. The operation is controlled by the control device 180 which carries out at least a post-heating operation for cooling the post-wafer 202 while controlling the temperature before the post-wafer 202 with bumps formed at the bonding stage 110 is stored in the second storage container 206, which is a characteristic operation of the embodiment to be detailed later. Although the wafers 201, 202 in the following description are 3-inch compound semiconductor wafers, needless to say, a type and a size of the wafers are not restricted to this.

[0023]

The first lifter 151 operates to move up or down

the first storage container 205 so that the pre-wafer 201 is disposed to a take-out position where the wafer can be taken out from the first storage container 205 by the carry-in device 131. As shown in Fig. 7, in a step (indicated by "S" in the drawing) 1, the carry-in device 131 moves to the first storage container 205, and the move-side holding member 1311 and the fixed-side holding member 1312 of the carry-in device 131 hold the pre-wafer 201. In a next step 2, the held wafer 201 is taken out from the first storage container 205 and transferred. In a following step 3, the holding part 141 of the load and transfer device 140 moves to above the pre-wafer 201 held by the carry-in device 131, the move part 143 of the load and transfer device 140 drives to lower the holding part 141, and moreover the cylinder 14131 of the holding part 141 drives to separate the first clamp member 1411 and separate the second clamp member 1412. The cylinder 14131 operates to bring close the first clamp member 1411 and bring the second clamp member 1412, thereby holding the pre-wafer 201. In a succeeding step 4, the holding part 141 moves up and the drive part 142 shifts the holding part 141 to above the bonding stage 110.

[0024]

In the embodiment, before the pre-wafer 201 is placed on the bonding stage 110, in a step 5 as one of features of the embodiment, the pre-wafer 201 is preheated in a state while held by the holding part 141. If the pre-wafer 201 at normal temperature is immediately placed on the

bonding stage 110 and heated to a temperature for bump bonding which is approximately 150°C at maximum, the wafer if it is the compound semiconductor wafer sensitive to a temperature change probably develops a circuit destruction or the above-referred crack because of the pyroelectric effect. Thus, the wafer is preheated for avoiding this.

As a concrete way of the preheating, in the embodiment, the pre-wafer 201 held by the holding part 141 is arranged above the bonding stage 110 which is already heated to nearly the temperature for bump bonding, with a noncontact state opposite to the bonding stage 110, so that the wafer is heated by radiant heat from the bonding stage 110. A temperature-rise controlling of the pre-wafer 201 in the preheating method can be controlled by controlling at least either a size of a gap between the bonding stage 110 and the pre-wafer 201, or an arrangement time of the pre-wafer 201 at the position. Or a combination of the gap size and the arrangement time enables various kinds of control as shown in Figs. 8 and 9. Fig. 8 shows a case where the gap size and arrangement time are not changed during a preheating operation, in other words, showing a temperature rise curve in the case of a one-stage preheating type in which the pre-wafer 201 is placed on the bonding stage 110 at a time point when the pre-wafer 201 becomes an equilibrium state of a temperature of the pre-wafer 201 and then heated to the temperature for bump bonding. On the other hand, Fig. 9 shows a case where the gap size and

arrangement time are changed during the preheating operation, namely, the temperature rise curve in the case of a multiple-stage preheating type. In Figs. 8 and 9, t1, t2, t3, t4, t5 are times used for the preheating and, T1, T2, T3, T4 are temperatures in the equilibrium state in the preheating operation. T is the temperature for bump bonding. The temperature rise curve represented by 1001 corresponds to this embodiment, and has a temperature increase rate that it takes approximately 90 seconds to raise the temperature of the wafer to 80°C with the gap size being 4 mm. After the wafer is held for one to two minutes in the above condition, the wafer is placed on the bonding stage 110.

[0025]

A condition for selecting an appropriate control among the various temperature rise controls is selected on the basis of at least one of a material of the semiconductor wafer and a thickness of the semiconductor wafer. The material of the semiconductor wafer means, for example, a type of the wafer, that is, whether the wafer is a silicon wafer or compound semiconductor wafer, and further a kind of the compound of the semiconductor wafer.

Patterns of the various temperature rise controls may be stored as a program for the preheating into a memory part of the control device 180 beforehand, so that the control device 180 can automatically select a temperature rise control appropriate for the preheating on the basis of at least one of the material and thickness of the

semiconductor wafer input to the control device 180. Also the temperature rise control may be carried out on the basis of information on an actual temperature of the pre-wafer 201 which information is supplied to the control device 180 from the temperature measuring device 1419 set to the holding part 141.

The preheating is executed with utilization of heat of the bonding stage 110 in the embodiment. The preheating is not restricted to this way and a heating device for the preheating may be set separately.

The operation can shift from the step 4 directly to a step 6 describing below although the step 5 is executed in the embodiment.

[0026]

In the step 6, similar to the conventional bump forming apparatus, the load and transfer device 140 places the pre-wafer 201 onto the heated bonding stage 110, whereby the pre-wafer 201 is heated to the temperature for bump bonding. Then, the bump forming head 120 while being moved by the X, Y-table 122 to bump formation points forms bumps onto the wafer 201.

[0027]

After the bumps are formed to all required points, the load and transfer device 140 holds the post-wafer 202 from on the bonding stage 110 in a step 7. After the step 7, i.e., in either a step 8 or a step 9, the post-heat operation which is one of characteristic features of the

embodiment is carried out. If the post-wafer 202 at the temperature for bump bonding is immediately placed on the loading member 1321 at the normal temperature of the carry-out device 132, the heat is transmitted from the post-wafer 202 to the loading member 1321, thereby possibly breaking the semiconductor wafer when the semiconductor wafer is a compound semiconductor wafer which is sensitive to the temperature change, or bringing about the like trouble. For impeding this, the wafer 202 is cooled while a temperature drop is controlled. As a way of the post-heating, according to the embodiment, the post-wafer 202 is arranged above the bonding stage 110 by the load and transfer device 140, similar to the above preheating, which is carried out in the step 8, or the post-wafer 202 is disposed by the load and transfer device 140 to a cooling position other than above the bonding stage 110, for instance, above the loading member 1321 of the carry-out device 132 or the like, which is carried out in the step 9. In any way, the post-wafer 202 is prevented from immediately contacting the loading member 1321 of the normal temperature, and the temperature drop of the post-wafer 202 is delayed. The post-heating operation is not limited to these methods and can be carried out in various manners as described later.

[0028]

In the post-heating operation executed in the step 8, either or both of the gap size and arrangement time are changed in the same manner as the preheating operation

executed in the step 5, whereby the temperature drop is controlled to represent, for example as shown in Fig. 10, a temperature drop curve nearly inverse to the temperature rise curve shown in Figs. 8 and 9. A graph indicated by 1002 is the temperature drop curve when the gap size and arrangement time are not changed during the post-heating operation, similar to the aforementioned one-stage preheating type. On the other hand, a graph designated by 1003 is the temperature drop curve when the gap size and arrangement time are changed during the post-heating operation, similar to the multi-stage preheating type. t6, t7 are times spent for the post-heating, and T5, T6 are temperatures in an equilibrium state in the post-heating operation. T0 is the normal temperature. The post-wafer 202 is moved to the loading member 1321 of the carry-out device 132 at a time point when the above time t6, t7 has passed.

Similar to the preheating operation, the control on temperature drop is selected among various kinds on the basis of at least either of the material and the thickness of the wafer 201, 202.

Also similar to the preheating operation, patterns of various kinds of temperature drop controls may be stored beforehand as a program for the post-heating in the memory part of the control device 180, so that the temperature drop control appropriate to the post-heating is automatically selected by the control device 180 based on at least one of the material and thickness of the semiconductor wafer input

to the control device 180. Alternatively, the temperature drop control may be performed on the basis of information on an actual temperature of the post-wafer 202 which is supplied from the temperature measuring device 1419 of the holding part 141 to the control device 180.

The post-heating is executed in the embodiment with utilization of heat of the bonding stage 110, but not limited to this. A heating device for the post-heating may be set separately.

[0029]

Since the heat diverged from the bonding stage 110 will not act in the post-heating operation carried out in the step 9 different from the step 8, the temperature of the post-wafer 202 drops faster than in the step 8. However, a speed of the cooling is slow because of the absence of heat transmission to the loading member 1321 in comparison with the case when the wafer is placed onto the loading member 1321 immediately after bumps are formed, and consequently troubles such as the above-referred crack or the like are eliminated even from the above compound semiconductor wafer.

[0030]

Herein a relationship between rates of the temperature rise and temperature drop in the above preheating operation and post-heating operation, and the material and thickness of the semiconductor wafer will be described.

Silicon and quartz semiconductor wafers can be

relatively rapidly heated, cooled as compared with wafers of materials described below. For compound semiconductor wafers of lithium tantalum and lithium niobium, a rate of 50°C/min or lower is preferred against the crack in both the heating and the cooling, and in order to make sure the operation of the electric circuit, 3°C/min or lower is preferred. The operation of the electric circuit is sufficiently ensured even at a rate exceeding the above 3°C/min. The temperature rise rate of about 50°C/10 sec is allowed in some cases, whereas the temperature drop control is severer in condition. Although not determined yet at present, the above condition of the lithium tantalum and lithium niobium semiconductor wafers may support a condition for semiconductor wafers of gallium arsenide.

A clear relationship between the thickness and, the temperature rise rate and temperature drop rate has not been made sure at present. However, the wafer when held by the holding part of the transfer and load device is easier to deflect by a holding force of the holding part as the wafer is thinner. Therefore, a small thickness is considered disadvantageous.

[0031]

Although either the step 8 or the step 9 should be carried out and the embodiment carries out the step 9, an executed pattern is not limited to this. In other words, the step 8 and then the step 9 may be sequentially carried out in this order depending on the material and thickness.

Furthermore, since the temperature-controlled air can be sent by the air blast device 1325 as described earlier at the loading member 1321 of the embodiment, it is possible to preliminarily raise the loading member 1321 to not lower than the normal temperature by the air or, the temperature drop of the post-wafer 202 placed on the loading member 1321 can be delayed by the air. In such structure, the step 7 may be followed by a step 10 to be depicted below depending on the material and thickness of the semiconductor wafer.

The above-described arrangement of sending the temperature-controlled air from the loading member 1321 can also prevent generation of troubles such as the crack or the like to the compound semiconductor wafers.

Since the temperature drop of the wafer 202 is controllable by sending the temperature-controlled air as above, the wafer 202 can be moved onto the loading member 1321 without waiting for the temperature equilibrium state thereof by the post-heating. Therefore, if the apparatus has only one load and transfer device 140, the load and transfer device 140 can be more speedily freed from the operation of holding the wafer 202 for the post-heating, so that a lead time is shortened.

[0032]

In the step 10 after the step 8 or step 9, the post-wafer 202 is moved from the load and transfer device 140 to the loading member 1321 of the carry-out device 132.

In a step 11, the post-wafer 202 is transferred by

the carry-out device 132 to the second storage container 206. In a step 12, the post-wafer 202 is stored by the carry-out device 132 to the second storage container 206 set by the second lifter 152 to a height whereat the container can store the post-wafer 202. The operation from the above step 10 through step 12 is equal to the operation in the conventional art.

[0033]

According to the bump forming apparatus 101 and bump formation method of the embodiment as described hereinabove, the pre-wafer 201 is not directly heated by the bonding stage 110 to the temperature for bump bonding, but is preheated in the preheating operation while the temperature rise is controlled. Troubles such as the circuit break by the pyroelectric effect, crack because of thermal deformation and the like are prevented even when the compound semiconductor wafers sensitive to the temperature change are handled. Moreover, the post-wafer 202 is not directly moved onto the loading member 1321 of the normal-temperature of the carry-out device 132 from the temperature for bump bonding, but is cooled in the post-heating operation while the temperature drop is controlled. Therefore, generation of troubles such as the above circuit break, crack or the like is eliminated even when the compound semiconductor wafers are handled.

[0034]

As modified embodiments of the above-described

bump forming apparatus 101, following constitutions may be adopted.

In the above-described embodiment, the loading member 1321 of the carry-out device 132 is formed of a metallic sheet. A thermal insulating material, specifically a resin material in the embodiment may be set to a contact part of the loading member to the post-wafer 202, as in carry-out devices 251-253 shown in Figs. 11-13, whereby cooling the post-wafer 202 which is higher than the normal temperature can be delayed.

More specifically, in the carry-out device 251 in Fig. 11, a thermal insulating material 2512 is set on the metallic loading member 2511, thereby preventing the loading member 2511 from being in direct contact with the post-wafer 202. The thermal insulating material 2512 as a resin material makes heat of the post-wafer 202 hard to transmit to the loading member 2511. Furthermore, the thermal insulating material 2512 has projections 2513 so that the post-wafer 202 is brought in point contact with the thermal insulating material 2512 thereby obstructing the heat transmission more. In the constitution as above, the temperature drop of the post-wafer 202 can be delayed in comparison with the case where the post-wafer 202 is directly placed on the metallic loading member 1321.

[0035]

The carry-out device 252 in Fig. 12 has an air layer 2523 formed between the loading member 2521 and a

thermal insulating member 2522 in addition to the structure of the above carry-out device 251. The heat transmission from the insulating material 2522 to the metallic loading member 2521 is easy to shut by forming the air layer 2523 having a heat insulation effect, and therefore the temperature drop of the post-wafer 202 can be delayed more than in the above carry-out device 251.

The reason for setting the thermal insulating material on the metallic loading member as in the carry-out device 251 and carry-out device 252 is to make smooth a load face of the thermal insulating material where the post-wafer 202 is loaded by forming the smooth face to the metallic loading member to which a plane processing can be done easier. However, if the load face of the thermal insulating material can be made smooth easier, the loading member for the post-wafer 202 can be formed only of the thermal insulating material 2531 as in the carry-out device 253 shown in Fig. 13.

Since the speed for cooling the post-wafer 202 can be delayed in the carry-out devices 251-253 with the thermal insulating material as above, the step 8 or 9 may be and may not be carried out.

[0036]

As indicated in Fig. 14 exemplifying the carry-out device 251, a projection 2513 is set with gaps 2515 to the thermal insulating material 2512 and loading member 2511. When the post-wafer 202 moves in an orthogonal direction to

a thicknesswise direction thereof after loaded to the carry-out device 251, the projection 2513 alike can move together with the post-wafer 202 in the orthogonal direction at the gaps. If the projection is fixed while the post-wafer 202 moves, the projection and the post-wafer 202 rub each other thereby unfavorably damaging the post-wafer 202. However, the possibility of the damage is eliminated by adapting the projection 2513 to move with the post-wafer 202 in the same direction as above.

As shown in the drawing, the projection 2513 is provided to the thermal insulating material 2512 via the gap 2515 also in the thicknesswise direction of the post-wafer 202 and consequently can move also in the thicknesswise direction of the wafer 202.

The projection 2513 alone may be formed of a material different from the material of the thermal insulating material 2512, 2522, 2531.

[0037]

In order for thermally insulating the pre-wafer 201 and post-wafer 202 better than in the present embodiment, the load and transfer device 140 may be provided with a heat insulation device. Fig. 15 shows a load and transfer device 261 obtained by mounting a heat insulation device 262 to the load and transfer device 140.

The heat insulation device 262 has a member 2621 for covering, and a driving part 2624. The member 2621 for covering is a heat insulation member for the wafer 201, 202,

including an upper cover 2622 and a lower shutter 2623 which are arranged in the thicknesswise direction of the wafer 201, 202 and are arranged to cover the holding part 141 having the first clamp member 1411 and second clamp member 1412. The lower shutter 2623 is constituted of two lower shutters 2623-1, 2623-2 opened right and left by the driving part 2624 in a diametrical direction of the wafer 201, 202 held by the holding part 141. Each of the lower shutters 2623-1, 2623-2 has a plurality of openings 2625 formed penetrating the lower shutter 2623-1, 2623-2 so that the heat from the bonding stage 110 easily acts to the wafer 201, 202.

Because of the presence of the heat insulation device 262 constituted as above, when the wafer 201, 202 is disposed above the bonding stage 110 in the earlier-described step 5 and step 8 with the lower shutter 2623 closed and the wafer 201, 202 held, the heat of the bonding stage 110 enters to stay in the member 2621 for covering. As a result, the wafer 201, 202 can be insulated thermally.

[0038]

Moreover, the heat insulation device 262 can be equipped with a heat insulation assisting device 263 for blowing a temperature-controlled gas to assist heat insulation for the wafer 201, 202 to the wafer 201, 202 held within the member 2621 for covering. In the present embodiment, the gas is nitrogen gas, which is guided by a pipe 2631 to flow along a surface of the wafer 201, 202 and blown to the wafer 201, 202. The whole of the wafer 201,

202 can be kept at a uniform temperature by the blowing of the gas. Oxidation of electrodes formed on the wafer 201, 202 can be also prevented when the nitrogen gas or an inert gas is blown.

[0039]

For shortening the lead time in the bump formation process as well as preventing generation of troubles such as the break or the like to the wafer 201, 202, an arrangement to be described below can be provided in addition to the constitution of the above embodiment and its modified example.

More specifically, while the load and transfer device 140 of the embodiment has only one holding part 141 as discussed above, two holding parts 144-1, 144-2 may be provided as in a load and transfer device 144 of Fig. 4. Then the holding parts 144-1, 144-2 may be driven independently so that, for example, the holding part 144-1 loads and transfers pre-wafer 201, and the holding part 144-2 loads and transfers the post-wafer 202. The temperature measuring device 1419 is set to each of the holding parts 144-1, 144-2.

Each of operations for loading and transferring the pre-wafer 201 and post-wafer 202 can be shared to the holding parts respectively in the above constitution, so that the lead time can be shortened.

[0040]

In the case of only one load and transfer device

140, a temporary holding member 271 can be set to at least one of the carry-in device 131 and the carry-out device 132 as shown in Fig. 16. Supposing that the temporary holding member 271 set to the carry-in device 131 is a first temporary holding member 271-1 and the temporary holding member 271 set to the carry-out device 132 is a second temporary holding member 271-2, in the example of the carry-in device 131, the first temporary holding member 271-1 is formed in a U-shape so as to hold the loading member 1321 and is moved up and down in the thicknesswise direction of the wafer 202 placed on the loading member 1321 by a driving device 272 controlled in operation by the control device 180. When the first temporary holding member 271-1 is set as above, the wafer 201 can be delivered between the loading member 1321 and the first temporary holding member 271-1, while the loading member 1321 can take out a next pre-wafer 201. The lead time can be accordingly shortened. The operation and effect as above are equally achieved in the case of the second temporary holding member 271-2.

[0041]

As indicated in Fig. 17, in a bump forming apparatus 301 of the so-called single magazine type with only one storage container 302 for the wafers 201, 202, there are included a temporary holding member 303 with a heater in addition to the above temporary holding member, the above temporary holding member 304, a transfer device 305 for sending in, out the wafers 201, 202 to the storage

container 302, and a load and transfer device 306. According to the arrangement, for example, while the pre-wafer 201 taken out by the transfer device 305 is placed and preheated by the temporary holding member 303 with the heater, the next pre-wafer 201 can be taken by the freed transfer device 305 and the post-wafer 202 can be moved by the load and transfer device 306 to the temporary holding member 304 from the bonding stage 110. Since operations can be executed concurrently with the use of the temporary holding member, the lead time can be shortened even in the single magazine type. In the above constitution, the temporary holding member 303 with the heater is preferably provided with an appropriate cooling device because the temporary holding member 303 is required to be cooled to nearly the normal temperature after the preheating before the next pre-wafer 201 is loaded.

[0042]

Second Embodiment;

A semiconductor wafer having a semiconductor circuit formed on, e.g., a quartz substrate (referred to as a "quartz semiconductor wafer" hereinbelow) has a problem yet to be solved as shown below although the compound semiconductor wafer primarily exemplified in the foregoing description is less troubled. The quartz semiconductor wafer discussed here has a diameter of 3 inches and a thickness of 0.3-0.35mm, but is not limited to this size.

From a view point of facilitating bump formation

onto the semiconductor wafer, the temperature for bump bonding is preferably as high as possible, for instance, approximately 250-270°C for silicon wafers and approximately 150°C for lithium tantalum wafers. The quartz semiconductor wafer is not an exception. However, a phenomenon below takes place in experiments conducted by the applicant in which the preheated quartz semiconductor wafer is placed on the bonding stage set to various temperatures and heated to the temperature for bump bonding. Even when the bonding stage is gradually heated at a temperature rise rate of 5°C/min, a quartz semiconductor wafer 211 is warped as illustrated in Fig. 19 when the bonding stage reaches approximately 250°C, specifically, when a stage contact face 211b of the quartz semiconductor wafer 211 in contact with the bonding stage reaches the above temperature of the bonding stage, i.e., approximately 250°C. Also, if a temperature difference between the bonding stage and the quartz semiconductor wafer 211 immediately before placed on the bonding stage is approximately 50°C, the quartz semiconductor wafer 211 is warped as indicated in Fig. 19. The warpage is brought about if the quartz semiconductor wafer is rapidly heated, e.g., at the rate of 20°C/min even when the temperature difference is not larger than 50°C.

A concrete value of the warpage, i.e., a size I in Fig. 19 is approximately 2mm.

[0043]

The quartz semiconductor wafer 211 in a state in

which the wafer is warped cannot be sucked onto the bonding stage, and naturally bumps cannot be formed on the warped quartz semiconductor wafer 211. If the warped quartz semiconductor wafer 211 is forcibly sucked on the bonding stage, the quartz semiconductor wafer 211 cracks.

A cause of the warpage is considered to result substantially from physical properties of the quartz semiconductor wafer 211, but is directly a nonuniformity in temperature of the quartz semiconductor wafer 211 in the thicknesswise direction. In other words, although the stage contact face 211b of the quartz semiconductor wafer 211 is rapidly heated when placed on the bonding stage, a temperature rise speed of a circuit formation face 211a of the quartz semiconductor wafer 211 opposite to the stage contact face 211b is lower as compared with the stage contact face 211b, thereby bringing about a temperature difference between the stage contact face 211b and circuit formation face 211a. The temperature difference makes the warpage of the quartz semiconductor wafer.

[0044]

In the embodiment, a wafer temperature control device 160 is set as shown in Fig. 1 or 18, which controls the temperature difference between the circuit formation face 211a and the stage contact face 211b within a warpage non-generation temperature range where the warpage of the quartz semiconductor wafer 211 placed on the bonding stage 110 is restricted to an amount not impeding the bump

formation to the loaded quartz semiconductor wafer 211, specifically, 50μm in the embodiment. The above amount of the warpage corresponds to the size represented by "I" in Fig. 19 in a state before the quartz semiconductor wafer 211 warped to project is sucked to the bonding stage 110. When bumps are actually formed, the above 50μm becomes not larger than approximately 20μm because of the suction operation. The wafer temperature control device 160 heats the circuit formation face 211a of the quartz semiconductor wafer 211 placed on the bonding stage 110 or cools the stage contact face 211b so as to keep the temperature difference in the warpage non-generation temperature range. The warpage non-generation temperature range is within approximately 20°C based on the result of the experiments.

[0045]

In one form of heating the circuit formation face 211a, a heating air blow device 161 is set to the wafer temperature control device 160 as shown in a detailed manner in Fig. 18. The heating air blow device 161 is arranged at a position not to interfere with the operation of the bump forming head 120 in a back side of the bonding stage 110. The heating air blow device 161 blasts a heating air of a temperature which accommodates the temperature difference within the warpage non-generation temperature range to an entire area or almost the entire area of the circuit formation face 211a of the quartz semiconductor wafer 211 placed on the bonding stage 110. For example, the bonding

stage 110 is set to 200°C and the heating air of 200°C is sent out for approximately 30 seconds from the heating air blow device 161.

The position where the heating air blow device 161 is installed is not limited to the above and, e.g., can be arranged at a front side or the like of the bonding stage 110. The heating air blow device 161 is connected to the control device 180 and, the temperature, a blowing time, a volume, a velocity of the heating air and the like are controlled on the basis of a relationship to the temperature of the bonding stage 110.

[0046]

Meanwhile, a cooling air supply device 162 may be arranged in a way to cool the stage contact face 211b in the wafer temperature control device 160 as clearly indicated in Fig. 18. A plurality of suction holes 111 are formed in the bonding stage conventionally for sucking the semiconductor wafer, which are communicated with a suction device 113 through an air passage 112. The cooling air supply device 162 is connected to the air passage 122 and supplies a cooling air via the air passage 122 to an entire area or almost the entire area of the stage contact face 211b. Since projections 114 for positioning and supporting the placed semiconductor wafer are formed on the bonding stage 110 hitherto, the quartz semiconductor wafer 211 is prevented from dropping from on the bonding stage 110 as a result of the supply of the cooling air by the cooling air

supply device 162. The cooling air supply device 162 is connected to the control device 180 and, a temperature, a supply time, a volume, a velocity and the like of the cooling air are controlled on the basis of a relationship to the temperature of the bonding stage 110. In the embodiment, when the bonding stage 110 is set to 200°C, the cooling air is sent out from the cooling air supply device 162 for about 20 seconds. The cooling air temperature immediately after sent out from the cooling air supply device 162 and before reaching the stage contact face 211b is 185°C.

As a way for correcting the warpage, normally, setting the heating air blow device 161 for heating the circuit formation face 211a which is lower in temperature than the stage contact face 211b is preferred. However, in the case of setting the cooling air supply device 162, conveniently, since the existing air passage 112 can be utilized and an installation position thereof can be selected with a high degree of flexibility, the cooling air supply device 162 is more convenient than the heating air blow device 161.

[0047]

Operation of the wafer temperature control device 160 constituted as above will be discussed with reference to Fig. 20. The operation shown in Fig. 20 corresponds to operation in heating and bonding the quartz semiconductor wafer 211 in step 6 of Fig. 7. The cooling air supply device 162 is employed by way of example of the wafer

temperature control device 160 in the embodiment.

In the present embodiment, the bonding stage 110 is set to 200°C. As described before, since the temperature difference between the bonding stage 110 and the quartz semiconductor wafer 211 placed on the bonding stage 110 should be within approximately 50°C, the preheating is carried out in step 5 to the quartz semiconductor wafer 211. The preheating in this embodiment is conducted in two stages according to the embodiment as described with reference to Fig. 8. The quartz semiconductor wafer 211 is first raised to 100°C and then heated to 150°C. The circuit formation face 211a and stage contact face 211b of the quartz semiconductor wafer 211 become equal in temperature at a time point when the preheating is completed.

[0048]

In step 61, the quartz semiconductor wafer 211 is placed by the holding part 141 of the load and transfer device 140 onto the bonding stage 110. The quartz semiconductor wafer 211 is subjected to practical heating in step 62. Although the quartz semiconductor wafer 211 starts to be warped because the stage contact face 211b is quickly heated subsequent to the above placement on the bonding stage, a step 63 is executed simultaneously with the step 62. That is, the cooling air is supplied by the cooling air supply device 162 to the whole area or almost the whole area of the stage contact face 211b of the quartz semiconductor wafer 211 for about 20 seconds, so that a temperature

increase ratio of the stage contact face 211b is suppressed. The temperature difference between the circuit formation face 211a and the stage contact face 211b is thus kept within the warpage non-generation temperature range where the warpage of the quartz semiconductor wafer 211 is restricted to the amount of warpage of the wafer which does not obstruct formation of bumps to the quartz semiconductor wafer 211. Even if the warpage once generates, the warpage is corrected and therefore the warpage of the quartz semiconductor wafer 211 is kept in the above amount. According to the above operation, the quartz semiconductor wafer 211 is heated to the temperature for bonding, i.e., 200°C which is the set temperature of the bonding stage 110 in the embodiment.

In step 64, after being heated to the temperature for bonding, the quartz semiconductor wafer 211 is sucked onto the bonding stage 110 by the action of the suction device 113 and bumps are formed on the circuit formation part by the bump forming head 120.

The operation following the step 7 is carried out afterwards.

[0049]

According to the embodiment as above, the warpage of the quartz semiconductor wafer 211 is restricted at the practical heating within the amount of the warpage of the wafer whereby the formation of bumps is not hindered. Therefore, the quartz semiconductor wafer 211 can be heated

to high temperatures, e.g., 200-250°C with the warpage being kept to the above amount, and thus the bumps can be formed on the quartz semiconductor wafer 211.

[0050]

As described above, although the cooling air supply device 162 uniformly supplies the cooling air to the entire area or nearly the entire area of the stage contact face 211b, the temperature, a feed amount or the like of the air may be changed based on a position on the stage contact face 211b from a view point of more effectively preventing generation of the warpage. For instance, a cooling air supply device for supplying the cooling air to a central part of the quartz semiconductor wafer 211 and a cooling air supply device for supplying the cooling air to the other part may be provided, and the cooling air to the central part may be lowered in temperature or increased in amount than the cooling air to the other part.

[0051]

The quartz semiconductor wafer 211 is described by way of example in the foregoing description. However, the second embodiment is not limited to this wafer and useful to semiconductor wafers using a substance which poorly transmits heat and greatly changes a thermal expansion coefficient depending on temperatures.

[0052]

[Effects of the Invention]

According to the bump formation method in the first aspect and the bump forming apparatus in the third aspect of the present invention, there is employed the post-heating device which executes the post-heating operation for controlling a temperature drop of the wafer after bumps are formed on the wafer, whereby generation of troubles such as a circuit break by a pyroelectric effect, a crack by thermal deformation and the like can be prevented even when compound semiconductor wafers sensitive to a temperature change are handled.

[0053]

In the bump formation method of the second aspect and the bump forming apparatus of the fourth aspect of the present invention, the preheating device is further arranged in addition to the post-heating device, thereby heating the semiconductor wafer while controlling a temperature rise of the wafer before bumps are formed on the wafer. Thus even when compound semiconductor wafers sensitive to a temperature change are handled, generation of troubles such as a circuit break by a pyroelectric effect, a crack by thermal deformation and the like can be furthermore prevented.

[0054]

In the bump formation method of the fifth aspect and the bump forming apparatus of the sixth aspect of the present invention, the wafer temperature control device is additionally set to execute temperature control to the

semiconductor wafer placed on the bonding stage to suppress a warpage of the semiconductor wafer to a level not obstructing the bump formation. Thus the semiconductor wafer can be maintained in a nearly flat state even at high temperatures, e.g., 200-250°C, so that bumps can be formed on the semiconductor wafer at the high temperature.

[Brief Description Of The Drawings]

[Fig. 1] Fig. 1 is a perspective view of a bump forming apparatus according to an embodiment of the present invention.

[Fig. 2] Fig. 2 is a perspective view of a transfer device shown in Fig. 1.

[Fig. 3] Fig. 3 is a perspective view of a load and transfer device shown in Fig. 1.

[Fig. 4] Fig. 4 is a perspective view of a modification of the load and transfer device of Fig. 3.

[Fig. 5] Fig. 5 is a plan view of the load and transfer device of Fig. 3.

[Fig. 6] Fig. 6 is a sectional view of a clamp mechanism of the load and transfer device of Fig. 3.

[Fig. 7] Fig. 7 is a flow chart showing operations in a bump formation method carried out by the bump forming apparatus of Fig. 1.

[Fig. 8] Fig. 8 is a graph of various temperature rise curves at the time of preheating in step 5 of Fig. 7.

[Fig. 9] Fig. 9 is a graph of various temperature

rise curves at the preheating in step 5 of Fig. 7.

[Fig. 10] Fig. 10 is a graph of temperature drop curves in step 8 or 9 of Fig. 7.

[Fig. 11] Fig. 11 is a sectional view of a modified example of a carry-out device shown in Fig. 1.

[Fig. 12] Fig. 12 is a sectional view of a modified example of the carry-out device shown in Fig. 1.

[Fig. 13] Fig. 13 is a sectional view of a modified example of the carry-out device shown in Fig. 1.

[Fig. 14] Fig. 14 is a sectional view of a projecting part included to the carry-out device shown in Figs. 11-13.

[Fig. 15] Fig. 15 is a diagram of a modified example of the load and transfer device of Fig. 1.

[Fig. 16] Fig. 16 is a perspective view of a temporary holding member included in a modified example of the bump forming apparatus of Fig. 1.

[Fig. 17] Fig. 17 is a block diagram of a modified example of the bump forming apparatus of Fig. 1.

[Fig. 18] Fig. 18 is a perspective view of the bump forming apparatus in Fig. 1 in a state with a heating air blow device constituting a wafer temperature control device.

[Fig. 19] Fig. 19 is a diagram of a state in which a quartz semiconductor wafer is warp on a bonding stage.

[Fig. 20] Fig. 20 is a flow chart of operation in step 6 of Fig. 7 in the case where the bump forming apparatus of Fig. 1 is provided with the wafer temperature control device.

[Explanation of Reference Numerals]

101... bump forming apparatus, 110... bonding stage,
120... bump forming head, 130... transfer device,
131... carry-in device, 132... carry-out device,
140... transfer device, 144-1, 144-2... transfer device,
160... wafer temperature control device,
180... control device, 205... first storage container,
206... second storage container,
211... quartz semiconductor wafer,
211a... circuit formation face, 211b... stage contact face,
263... heat insulation assisting device,
271... temporary holding member, 1325... air blast device,
1411, 1412... clamp member, 1414... clamp mechanism,
1419... temperature measuring device,
2511, 2521... loading member,
2512, 2522... thermal insulating material,
2621... member for covering, and 2625... opening.